# DETERMINATION OF STACK GAS VELOCITY AND FLOW RATE IN EXHAUST STACKS, DUCTS, AND VENTS

**Purpose**

This Meteorology and Air Quality Group (MAQ) procedure describes the measurement of gas velocity and volumetric flow rate in LANL exhaust stacks, ducts, and vents using EPA Reference Methods 2 and 2C.

**Scope**

This procedure applies to all measurements of gas velocity and volumetric flow rate in LANL exhaust stacks for RRES-MAQ Compliance Projects.

**In this Procedure**



**Hazard Control Plan**

The hazard evaluation associated with this work is documented in Attachment 1: Initial risk = **low**. Residual risk = **low**. Work permits required: Radiation Work Permits, facility-specific permits.
First authorization review date is one year from group leader signature below; subsequent authorizations are on file in group office.

**Signatures**

| | |
|---|---|
| Prepared by: Victor L. Martinez ?<br>Victor Martinez, MAQ | Date:<br>12/02/2003 |
| Approved by: David P. Fuehne<br>Dave Fuehne, Rad-NESHAP Project Leader | Date:<br>12/02/2003 |
| Work authorized by: Jean M Dewart<br>Jean Dewart, MAQ Group Leader | Date:<br>12/02/2003 |

12/3/03

# General information

**Signatures,** *continued*

| Approved by: | Date: |
|---|---|
| Terry Morgan, Quality Assurance Officer | 12/02/2003 |

12/03/03

**Attachments**

| Number | Attachment Title | No. of pages |
|---|---|---|
| 1 | Hazard Control Plan | 3 |
| 2 | Exhaust Stack Air Flow Measurement Schedule | 2 |
| 3 | Velocity Measurement Input Form (Form 5-M) | 2 |
| 4 | Velocity Measurement Input Form (2 x 12 Round Stack or Duct) (Form 5-R) | 1 |
| 5 | Velocity Measurement Input Form (6 x 5 Rectangular Stack or Duct) (Form 5-S) | 1 |
| 6 | Velocity Measurement Input Continuation (Form 5-C) | 1 |
| 7 | Stack Flow Data Transcription and Entry Verification | 1 |
| 8 | Flow Measurement Calculation Form (Form 6) | 2 |
| 9 | Cross-Sectional Area Worksheet (Round Exhaust Stack/Duct) (Form 7-R) | 1 |
| 10 | Cross-Sectional Area Worksheet (Rectangular Exhaust Stack/Duct) (Form 7-S) | 1 |

**History of revision**

This table lists the revision history and effective dates of this procedure.

| Revision | Date | Description of Changes |
|---|---|---|
| 0 | 4/24/98 | New procedure replaces JCNNM procedure MOI 41-30-009, “Exhaust Stack Air Flow Measurements.” |
| 1 | 2/1/00 | Restructured text and attachments and revised many steps. |
| 2 | 2/20/01 | Incorporated use of the new Access database, added wording to clarify procedural steps, deleted reference to JCNNM Engineer, and minor editorial corrections. |
| 3 | 6/4/02 | Modify testing frequency and change group designation. |
| 4 | 12/4/03 | Transition program from KSL to URS, clarify and expand on testing procedure, include electronic downloads from TSI, separate pitot tube chapters to new procedure (MAQ-141). |

# **General information**, continued

**Who requires training to this procedure?**

The following personnel require training before implementing this procedure:

- Task order contract personnel who perform flow measurements or support MAQ Compliance Programs that require exhaust stack flow measurements.
- MAQ technicians and staff members who support MAQ Compliance Programs that require exhaust stack flow measurements.

**Training method**

The training methods for this procedure are:

- **Self study <u>and</u> on-the-job** training for personnel ***performing*** flow measurements.
- **Self-study** (**reading**) for personnel ***supporting*** the flow measurement program and for those previously trained to Revision 3 of this procedure.

Amount of **on-the-job training** to be determined by the Rad-NESHAP Project Leader. Task order contractor will demonstrate proficiency in performing this procedure by passing an informal audit conducted by the MAQ Engineer.

Annual retraining is required and will be by "self-study" (reading). Training is documented in accordance with the procedure for training (MAQ-024).

**Prerequisites**

In addition to training to this procedure, the following training or surveillance programs are also required for technicians and staff members prior to performing flow measurements:

- Radiological Worker II Training
- Site-specific training as required for each facility
- Basic Fall Protection, Course #13079
- Beryllium Health Hazards, Course #725
- MAQ-026, "Deficiency Reporting and Correcting"

**Recommended training**

The following training is recommended, but not required:

- Tritium Safety
- Plutonium Safety
- Hazard Communication Introduction

# General information, continued

**Definitions specific to this procedure**

ACFM: Actual Cubic Feet per Minute, adjusted for temperature and pressure

EDM: Electronic Digital Manometer

HEPA: High Efficiency Particulate Air filter

NIST: National Institute of Standards and Technology

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**References**

The following documents are referenced in this procedure:

**National Codes and Standards**

- 40 CFR 61 Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities"
- 40 CFR 60 Appendix A Test Method 1, "Sample And Velocity Traverses For Stationary Sources"
- 40 CFR 60 Appendix A Test Method 1A, "Sample And Velocity Traverses For Stationary Sources With Small Stacks Or Ducts"
- 40 CFR 60 Appendix A Test Method 2, "Determination Of Stack Gas Velocity And Volumetric Flow Rate (Type S Pitot Tube)"
- 40 CFR 60 Appendix A Test Method 2C, "Determination Of Stack Gas Velocity And Volumetric Flow Rate In Small Stacks Or Ducts (Standard Pitot Tube)"
- 40 CFR 60 Appendix A Test Method 3, "Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight"
- 40 CFR 60 Appendix A Test Method 4, "Determination of Moisture Content in Stack Gases"
- 40 CFR 60 Appendix A Test Method 5, "Determination of Particulate Emissions From Stationary Sources"

**Los Alamos National Laboratory Requirements**

- LIR 402-704-01, "Contamination Control"
- OST308-00-00, "Laboratory Calibration Program" [http://www.esa-mt.lanl.gov/s&cl/calprog.html]

# **General information**, continued

**References**, *continued*

**MAQ procedures and plan**

- MAQ-RN, "Quality Assurance Project Plan for the Rad-NESHAP Compliance Project"
- MAQ-024, "Personnel Training"
- MAQ-026, "Deficiency Reporting and Correcting"
- MAQ-141, "Calibration and Evaluation of Pitot Tubes for Stack Flow Measurements"
- MAQ-BM, "Quality Assurance Project Plan for Beryllium Stack Monitoring at TA-3-141"

**Literature**

- Refer to the manufacturer's literature for each instrument
- Memorandum ESH-17:95-739, "Exhaust Stack Volumetric Flow Rate and Sample Flow Rate Reporting"
- Memorandum ESH-17:00-223, "Modified Traverse Spacing for Rad-NESHAP Monitored Stacks"

# Performance of Work

**General**

The task order contractor performing the stack flow measurements will coordinate all work, in support of the MAQ Compliance Programs, with the appropriate facility coordinators and facility management units.

**Facility check-in and check-out**

Special check-in and check-out procedures must be followed when working in all LANL facilities. Personnel assigned to perform the stack flow measurements shall ensure that all check-in and check-out procedures are followed as outlined in the facility's site-specific training.

**Measurement frequency**

Air flow measurements are performed on exhaust stacks that are sampled continuously for radionuclides and beryllium at the following frequency:

- Quarterly or semi-annually according to the attached testing schedule. The attached testing schedule may be modified slightly during the test year and will be issued yearly to reflect changes;
- within thirty days after a HEPA filter change or other pollution control device which could effect the flow rate through the stack;
- within thirty days after a major change to the ventilation system that could effect the flow rate, or;
- at the direction of the Rad-NESHAP Project Leader.

See Attachment 2 for the proposed annual schedule for all stack measurements. This schedule may be modified as needed by the Rad-NESHAP Project leader.

**Off-schedule measurements**

If a special flow measurement is performed outside of the normal schedule, **do not reschedule** the next routine measurement. For example, if a routine semi-annual flow measurement is performed in January, and a HEPA filter change occurs in February which results in a special flow measurement, perform the next routine measurement in July, not August.

# **Performance of Work**, continued

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**Rescheduling measurements**

If a routine flow measurement cannot be performed during its scheduled month, reschedule the flow measurement within 10 working days after the end of the scheduled month or within 10 days of obtaining approval from the facility. Submit any forms for late flow measurements to the appointed MAQ QA reviewer immediately after completion of flow measurement and equipment verifications. If a routine flow measurement must be skipped due to factors beyond the control of MAQ and/or the contractor performing the measurements, the **MAQ engineer must** fully document the circumstances surrounding the skipped flow measurement with an official memo to the file.

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**Duplicate flow measurements**

Every six months, perform a duplicate flow measurement within one week of the original flow measurement. The **MAQ engineer** will randomly select one exhaust stack per measurement cycle for the duplicate flow measurement to verify precision and accuracy requirements. This schedule may be modified during the year to account for any unforeseen scheduling problems. This duplicate flow measurement demonstrates the precision of the measurement methodology, as required by MAQ-RN ("Quality Assurance Project Plan for the Rad-NESHAP Compliance Project").

# Safety and hazard analysis

**ES&H hazard screening**

All hazards shall be identified and mitigated according to the Integrated Work Management Process. This new process is an overlay of the existing work control process and serves the same purpose as hazard control plans and activity hazard analyses.

**Potential hazards to consider**

The following types of hazards may be present during air flow measurements and must be identified in the appropriate integrated work document (IWD):

- radiation
- chemical emissions
- rotating machinery
- heights (e.g., roofs, scaffolding, bucket truck, etc.)
- weather (e.g., lightning, snow, ice, etc.)
- noise
- heat exposure
- falling objects
- compressed air

**Radiological hazards**

Before scheduling access to roof tops or opening stack measurement ports, contact facility operational personnel, area work supervisors, and local RCTs to determine if planned laboratory processes could be producing unusual radiological hazards during the stack measurements.

**Potentially contaminated equipment**

Equipment used to measure airflow in potentially radioactive stacks must be cleared by the site radiological control technician in accordance with facility requirements and LIR 402-704-01, “Contamination Control.” If radioactive contamination is detected, trained and qualified personnel must decontaminate the unit before it may be removed from the site.

**Personal protection equipment**

Safety shoes and safety glasses must be worn while performing all airflow measurements. The following additional personal protective equipment may be required and will be indicated in the facility IWD document:

- Hard hat
- Hearing protection
- Anti-contamination clothing including rubber gloves and booties
- Respirator

**Permits**

All permits (e.g., radiation work permits, confined space, etc.) must be issued and approved by the facility before work can be performed.

# Equipment specifications and calibration

**Acceptable equipment**

Specifications for equipment to be used to perform this procedure are given below. Other equipment meeting these specifications may be acceptable. **MAQ must obtain approval from EPA for substitute equipment not specified below.**

**Equipment calibration records**

Documented proof of calibration must be available for all measurement tools and instruments. The **individual responsible for calibration** files official calibration certificates in the MAQ records center and ensures each piece of equipment is marked with a calibration sticker (see OST308-00-00, "Laboratory Calibration Program" [http://www.esa-mt.lanl.gov/s&cl/calprog.html]).

**Users manuals**

Ensure a copy of the users' manual is on file for all equipment used to collect measurements.

**Pitot tubes**

See MAQ-141 for specifications and calibration of acceptable pitot tubes.

**Differential pressure gage**

An inclined manometer or equivalent device must be used. For measurement of $\Delta p$ values as low as 0.05 in. $H_2O$, use an inclined-vertical manometer having 0.01 inch $H_2O$ divisions on the 0-to-1 inch inclined scale and 0.1 inch $H_2O$ divisions on the 1-to-10 inch vertical scale.

If a differential pressure gage other than an inclined manometer is used (such as an EDM), the instrument calibration **must be checked after performing stack flow measurements** (see chapter *Post-Measurement Verifications*).

A differential pressure gage of greater sensitivity must be used, **but must first be approved by EPA**, if any of the following occur:

- the arithmetic average of all VP readings at the traverse points in the stack is less than 0.05 in. $H_2O$
- for traverses of 12 or more points, more than 10 percent of the individual VP readings are below 0.05 in. $H_2O$
- for traverses of fewer than 12 points, more than one VP reading is below 0.05 in. $H_2O$

*(continued on next page)*

# **Equipment specifications and calibration**, continued

***(continued)***

As an alternative to the above criteria, the following calculation may be performed to determine the need to use a more sensitive differential pressure gage:

$$T = \frac{\sum_{i=1}^{n}\sqrt{VPi + K}}{\sum_{i=1}^{n}\sqrt{VPi}}$$

Where: $VP_i$ = Individual velocity head reading at a traverse point, in. $H_2O$
n = Total number of traverse points
K = 0.005 in. $H_2O$

If T is greater than 1.05, the velocity head data are unacceptable and a more sensitive differential pressure gage must be used.

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**Electronic Digital Manometer**

An Electronic Digital Manometer (EDM) used (instead of an oil-gage manometer) to measure the airflow in the stacks must be calibrated annually by ESA-AET or the manufacturer. Calibration must be traceable to NIST standards.

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**Acceptable temperature gage**

Use a thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer (not recommended for portable use due to potential breakage and cleanup liabilities), or other gage, capable of measuring temperature to within 1.5 percent of the minimum absolute stack temperature in degrees Rankine. Attach the temperature gage to the pitot tube such that the sensor tip does not touch metal. The temperature gage must not interfere with the pitot tube face openings.

**NOTE**: Alternative positions for the temperature gage may be used if the pitot tube-temperature gage system is calibrated according to the procedure MAQ-141 (“Calibration and Evaluation of Pitot Tubes for Stack Flow Measurements”).

# Equipment specifications and calibration, continued

**Calibration of temperature gages**

Temperature gages used to measure air temperature in stacks must be calibrated annually by ESA-AET. Calibrations must be traceable to NIST standards.

Furthermore, at the end of the testing day, check the calibration of the thermometer used to perform the airflow measurement with a reference thermometer. The calibration check must be performed at a temperature within 10 percent of the average absolute stack temperature. The average absolute stack temperature is calculated using the following formula:

$$°R = °F + 460$$

- For temperatures up to 761 °F, use an ASTM mercury-in-glass reference thermometer, or equivalent, as the reference.
- If, during calibration, the absolute temperature measured with the temperature gage being calibrated and the reference thermometer agree within 1.5 percent, the temperature data taken in the field is considered valid. Otherwise, the airflow measurement must either be considered invalid or adjustments (if appropriate) to the test results must be made. **Any adjustments to the test results must be approved by EPA before the results may be used in emission calculations by MAQ.**

**Pressure probe and gage**

A piezometer tube and mercury- or water-filled U-tube manometer capable of measuring stack pressure to within 0.1 in. Hg are called for in the EPA test method. Use the static tip of a standard type pitot tube or one leg of a Type-S pitot tube (with face opening planes positioned parallel to the gas flow) to measure static pressure.

**Acceptable barometer types**

Use a mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 0.1 in. Hg. If the barometer is not located at the measuring site, adjust the barometric reading for elevation differences between the barometer (e.g., meteorology tower) and the sampling point. Adjust the reading minus 0.1 in. Hg per 100 foot elevation increase or plus 0.1 in. Hg per 100 foot elevation decrease.

# Equipment specifications and calibration, continued

**Calibration of barometer**

The barometer used to read atmospheric pressure is required to be calibrated annually. Calibration requirements are:

- The barometer aneroid must be calibrated annually by ESA-AET or the manufacturer.
- The barometer aneroid reading must be verified and corrected (accounting for elevation differences) semi-annually to the official MAQ meteorology section barometer.
- Alternatively, the barometric pressure may also be obtained directly from the official MAQ meteorology section barometer or from the LANL weather machine located on the internet. Calibration records for this barometer are maintained by the meteorology section of MAQ.

Document this calibration check in a memo or e-mail to the records.

**Gas density determination equipment**

Use EPA Method 3 equipment to determine the stack gas dry molecular weight. For processes emitting essentially air, an analysis need not be performed. Use a dry molecular weight of 29.0.

**Acceptable moisture content determination equipment**

Use a hand-held relative humidity meter capable of measuring the moisture content of the exhaust air to within ±1.5%.

**NOTE**: The relative humidity in the exhaust stack is measured for information purposes only. A value of 0% relative humidity is used in performing the final air flow calculation. This produces a slightly higher flow rate value than if the actual relative humidity was used. Refer to memorandum ESH-17:95-739 for details.

**Calibration of relative humidity meter**

Relative humidity meters used to measure the moisture content of the air in the exhaust stack should be calibrated annually by ESA-AET. If calibrated, the calibration must be traceable to NIST standards. Alternatively, a calibration check of the relative humidity meter must be performed annually against the relative humidity measured at one of the RRES-MAQ weather stations. This calibration check must agree to within ±10%. The relative humidity reading is not used in any calculations of airflow but is recorded as an indicator only. Document this calibration check in a memo or e-mail to the records.

# Measuring stack cross section

**Background**

The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head.

**Applicability**

This procedure must be followed for measurement of the average velocity of a gas stream and for quantifying gas flow. This procedure does not apply at measurement sites that fail to meet the criteria of EPA Reference Method 1 or 1A. Also, this procedure cannot be used for direct measurement in cyclonic or swirling gas streams in excess of regulatory limits.

**Exhaust stack measurement location (i.e., profile location)**

The **MAQ Engineer** will specify the location on the exhaust stack to perform airflow measurements, the number of traverses, the number of measurement points, and their spacing along each traverse. When an exhaust stack or duct is not perfectly round, the traverse spacing is determined per memo ESH-17:00-223. The number of traverses and the number of measurement points defines the measurement matrix.

The measurement location must meet the criteria of EPA Reference Method 1. If field conditions have changed (e.g., flow disturbances have been added to the ventilation system at the measurement point), do not perform the flow measurement. Contact the MAQ Engineer for further direction.

**Field measurement forms**

Record all measurement field data on the appropriate forms:

- Velocity Measurement Input Form (Form 5-M) (see example in Attachment 3)
- Velocity Measurement Input Form (2 x 12 Round Stack or Duct) (Form 5-R) (see example in Attachment 4)
- Velocity Measurement Input Form (6 x 5 Rectangular Stack or Duct) (Form 5-S) (see example in Attachment 5)
- Velocity Measurement Input Continuation Form (Form 5-C) (see example in Attachment 6), as necessary

**How to record data**

Record all entries in ink. Correct any errors by striking through the erroneous entry with a single line and annotating the correct information in an empty space directly adjacent to the error. Initial the correction.

# **Measuring stack cross section**, continued

**Measure stack cross-sectional area**

The cross-sectional area of each measuring location must be known. This needs to be performed only once for each location. If the cross sectional area has not been previously measured, follow the steps below.

**Steps to measure cross-sectional area**

To measure the cross-sectional area at a measurement location, perform the following steps:

| Step | Action |
|---|---|
| 1 | Make a rough sketch of the cross-sectional area on the stack or duct in section 1 of the "Cross-Sectional Area Worksheet (Round Exhaust Stack/Duct) (Form 7-R)" or "Cross-Sectional Area Worksheet (Rectangular Exhaust Stack/Duct) (Form 7-S)" (see examples in Attachments 9 or 10). Show:<br>• the traverses<br>• the orientation of the duct (vertical, horizontal)<br>• label north/south/east/west, if appropriate<br>• label up/down, if appropriate<br>• the direction of air flow<br>• indicate exterior items (i.e., the fan) which would help someone else align the traverses |
| 2 | Measure the inside duct dimensions. For round and oval stacks, measure each traverse diameter to the nearest 1/8 inch. For rectangular stacks, measure the widths (front and back face) and the depths (both sides) to the nearest 1/8 inch. Convert the fractional measurements to decimal format. For round stacks or ducts, calculate the average inside diameter. For oval stacks or ducts, record the actual measured diameters. Record this information in section 2 of the Cross-Sectional Area Worksheet (either Form 7-R or Form 7-S). |

*Steps continued on next page.*

# **Measuring stack cross section**, continued

| Step | Action |
|---|---|
| 3 | Calculate the area.<br><br>Round: $Area = \pi \left[\frac{d}{2}\right]^2 \left[\frac{1}{144}\right]$ sq feet<br><br>Oval: $Area = \frac{\pi * d_1 * d_2}{576}$ sq feet<br><br>Rectangular: $Area = \left[\frac{W1 + W2}{2}\right]\left[\frac{D1 + D2}{2}\right]\left[\frac{1}{144}\right]$ sq feet<br><br>Do not round values during calculation. Round the final value for the area to 3 decimal places. Record the area in section 3 of the Exhaust Stack or Duct Cross-Sectional Area Worksheet (either Form 7-R or Form 7-S). |
| 4 | Sign and date the Cross-Sectional Area Worksheet (either Form 7-R or Form 7-S). Both the person making the measurements and the person performing the calculations must sign and date this form. Forward the completed form to the MAQ Engineer who will review and approve the measurement. The Cross-Sectional Area Worksheets must be file in the official records center and the appropriate changes must be made in the STACKS database. |

*Steps continued on next page.*

# Measuring flow

**Field conditions**

Only perform airflow measurements when an exhaust stack, duct, or vent is exhausting ambient air from a laboratory or facility. Verify no hazardous operations are being vented through the stack by following proper check-in procedures at the facility. Notify the operations center, facility coordinator, area work supervisor, and/or the local RCT to ensure the ventilation system is under normal operations and no hazardous operations are taking place.

**Personnel roles**

A minimum of two people are needed to perform flow measurements. One person acts as data recorder and the other person wears appropriate PPE to handle all potentially contaminated equipment.

**Special tools or equipment**

The following tools and equipment are also needed to perform this procedure:

- Pitot tube level
- Pitot tube square
- Compressed air canister (non-ozone depleting)
- Hand pump capable of pressurizing or creating a vacuum of ±3 inches $H_2O$
- EPA Test Method 2 wind tunnel (Located at TA-35).

**Facilities with high stack velocities**

If the stack velocity at a facility (based on historical data) is in excess of 3,000 feet per minute (e.g., CMR Facility), a second EDM is needed to verify these high EDM readings.

**Steps to measure flow**

To measure flow in a stack, duct, or vent, perform the following steps:

| Step | Action |
|---|---|
| **Determining the location for performing measurements** | |
| 1 | Obtain the appropriate measurement forms and location on the stack or duct for performing the measurement from MAQ. The location is given by the profile measurement number.<br><br>**NOTE:** Acceptable locations are determined by MAQ by using EPA Method 1 for a stack or duct diameters 12 inches or larger; and by EPA Method 1A for diameters less than 12 inches, but not smaller than 4 in. |

*Steps continued on next page.*

# **Measuring flow**, continued

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td colspan="2">Preparing measurement input forms</td></tr>
<tr><td>2</td><td>Verify the TA, building, exhaust stack (ES) ID Number and exhaust fan(s) numbers have been entered correctly on the top of the official Velocity Measurement Input Form, Form 5-M. Record or verify the measurement profile number, the fan configuration, the type of measurement (quarterly, semi-annual, special, other), and the test method used.</td></tr>
<tr><td colspan="2">Selecting and preparing equipment</td></tr>
<tr><td>3</td><td>Select the correct pitot tube(s) for the stack(s) to be analyzed.<br><br>
<table>
<tr><th>For stack or duct…</th><th>use…</th></tr>
<tr><td>≥ 12” diameter or ≥ 113 in.$^2$ cross-sectional area</td><td>Type-S pitot tube or standard pitot tube.</td></tr>
<tr><td>< 12” diameter or < 113 in.$^2$ but ≥ 4” diameter or ≥ 12.57 in.$^2$ cross-sectional area</td><td>Standard pitot tube or approved alternative pitot tube. Do <u>not</u> use a Type-S pitot tube.</td></tr>
</table>
<br>The tip of the pitot tube(s) must be free of any damage. Each tube must be long enough to reach all traverse points along the cross-section of the stack(s). Calculate the distances from the centerline of the pitot nozzle opening to each traverse point. Mark the tube with a felt-tipped pen so that the pitot can be correctly positioned from the hole in the stack wall to each traverse point. Verify the location of the markings by having a second qualified stack measurement person check the marks. Check the appropriate box in section 1 indicating traverse spacing has been verified.</td></tr>
<tr><td colspan="2">Recording equipment calibration</td></tr>
<tr><td>4</td><td>Record the following in section 1 of the Velocity Measurement Input Form (Form 5-M):<ul><li>Manometer type (e.g., EDM), serial number, calibration expiration date;</li><li>Thermometer type, serial number, calibration expiration date;</li><li>Relative humidity meter, serial number, calibration expiration date;</li><li>Pitot tube type (e.g., Type-S) and serial number</li></ul>Verify that the EDM, relative humidity meter, and thermometer calibration certifications have not expired.</td></tr>
</table>

*Steps continued on next page.*

## **Measuring flow**, continued

| Step | Action |
|---|---|
| **Verifying exhaust system is exhausting ambient air and inspecting system** | |
| 5 | Check in with the facility coordinator or operations center before starting the flow measurements. Verify with the facility coordinator that the stack is not exhausting abnormal levels of radioactive or other hazardous process air and that the system is under normal operating conditions. Only perform airflow measurements when an exhaust stack, duct, or vent is exhausting ambient air from a laboratory or facility. |
| 6 | Before measuring the airflow, perform an informal inspection of the exhaust system to identify any unusual conditions or variations in the configuration of the exhaust system. Record any unusual findings in section 2 of the Velocity Measurement Input Form. Report these findings to the facility representative and determine if the facility will allow the work to proceed under the observed conditions. |
| **Setting up and adjusting equipment** | |
| 7 | Before connecting the EDM to the tubing, perform a zeroing function on the instrument. If the EDM does not "zero," record the Δp offset. If the Δp offset is greater than 0.01" $H_2O$, **DO NOT USE** this EDM. Replace the EDM with a backup instrument and send instrument to manufacturer for recalibration and/or repair. |
| 8 | Connect the EDM to the pitot tube using rubber capillary tubing. To measure velocity pressure, connect the total pressure port of the pitot tube to the "+" port of the EDM. Connect the static pressure port of the pitot tube to the "-" port of the EDM. Record a check in the appropriate box in section 3 of the Velocity Measurement Input Form. |

*Steps continued on next page.*

# **Measuring flow**, continued

| Step | Action |
|---|---|
| 9 | **<u>Optional</u>** <u>but recommended</u>: Perform a pre-measurement leak check on the capillary tubing installed between the EDM and the pitot tube. The capillary tubing must be air tight, holding a pressure of at least 3 inches of $H_2O$ for 15 seconds. **Do Not Pressurize The Tube By Mouth!**<br>• Seal the total pressure side of the pitot tube using a latex glove. Blow or pump dry air into the total pressure side of the system until at least 3 inches of pressure registers on the EDM. Close off the tube using the installed valve. The pressure reading should remain stable for at least 15 seconds.<br>• Next, seal the static pressure side of the pitot tube using a latex glove. Pull a 3 inch vacuum on the static pressure side. Close off the tube using the installed valve. The negative pressure reading should remain stable for at least 15 seconds after the tube is closed.<br>Record a check in the appropriate box in section 3 of the Velocity Measurement Input Form (Form 5-M). If the system does not pass the leak test, correct the problem, perform a second leak check test and document the problem and solution. |
| 10 | If not done automatically by the instrument, adjust the EDM sensitivity to the gage setting recommended by the manufacturer for the velocity pressure anticipated (from past measurements). Record a check in the appropriate box in section 3 of the Velocity Measurement Input Form (Form 5-M). |
| **Performing traverse readings** | |
| 11 | Verify the EDM zeros with the attached pitot tube and tubing. Because the EDM reading and zero may drift due to vibrations and temperature changes, perform a zero check between traverses. Record a check in the appropriate box in section 3 of the Velocity Measurement Input Form. |
| 12 | Record the time of the first reading in section 4 of the Velocity Measurement Input Form (Form 5-M). |
| 13 | One person: don minimum PPE: latex gloves or equivalent and safety glasses. Other PPE may be required by the facility. |
| 14 | Remove the traverse measurement port and insert the pitot tube. Only open the traverse port that is currently being used. |
| 15 | If possible, seal the space between the stack wall and the pitot tube using duct tape or other similar material. |

*Steps continued on next page.*

# **Measuring flow**, continued

| Step | Action |
|---|---|
| 16 | Verify with a level and square that the pitot tube is perpendicular to the cross-sectional plane of the stack and that the tube tip is parallel to the centerline of the stack before recording each velocity pressure reading. This may also be accomplished on most exhaust stacks by using the magnetic square and leveling tool.<br><br>**IMPORTANT: The pitot tube MUST be level and the tip MUST be parallel to the centerline of the stack to ensure accurate measurement of the velocity pressure.** |
| 17 | Measure the velocity pressures at all traverse points specified by MAQ (determined by MAQ by using EPA Reference Method 1 or 1A). Record the results on the appropriate Velocity Measurement Input Form (in Attachment 3, 4, or 5).<br><br>Because the EDM display readings are not always stable, utilize the “sample” feature of the EDM. Record two readings at each traverse measurement point. Each traverse must be given a different test ID number. Make a note on the data form indicating which test ID corresponds to which traverse. Average the two velocity pressure readings and report the average velocity pressure on the official form along with the measured temperature at each traverse point. Reinsert the plug in the stack port after each traverse has been completed.<br><br>**Caution:** Ensure that the proper EDM scale is being used for the range of VP values encountered. If it is necessary to change to a more sensitive gage, do so, and re-measure the VP at each traverse point. |
| 18 | Record the temperature of the air at each traverse point. Since the air within the stack or duct is primarily composed of conditioned laboratory air, it is only necessary to measure the temperature of the stack air at a few traverse points to ensure temperature uniformity. If large temperature gradients are found between the measured points, perform an entire temperature traverse at the same points where velocity pressure is read, as described above. |
| 19 | **<u>Mandatory</u>**: Perform a post-test leak check on the capillary tubing installed between the EDM and the pitot tube in the same manner as described in step 9.<br><br>Record a check in the appropriate box in section 6 of the Velocity Measurement Input Form (Form 5-M). If the system does not pass the leak test, void the measurement. Correct and document the problem and repeat the flow measurements starting with step 12. |

*Steps continued on next page.*

# **Measuring flow**, continued

| Step | Action |
|---|---|
| 20 | Measure the static pressure in the stack using the static pressure leg of the pitot tube. Connect the static pressure leg of the pitot tube to the "+" port of the EDM. One reading at the approximate center of the stack is usually sufficient. Record the measurement in section 7 of the Velocity Measurement Input Form (Form 5-M). |
| 21 | If any velocity pressure reading is over 0.75 inches of water, use a second EDM to verify such velocity pressure readings. Record this verification reading as test number 3 on section 13 of Form 5M. |
| 22 | Determine the moisture content of the exhaust air by using a hand held relative humidity meter. Record the relative humidity reading in section 7 of the Velocity Measurement Input Form (Form 5-M). |
| 23 | Before plugging the last hole, the standard pitot tube (this step not required for Type-S pitot tube) must be cleared and tested to validate the velocity pressure readings. Use a can of compressed air to 'back-purge' the pitot tube. Ensure the can of compressed air is held upright so that no moisture is introduced into the interior of the pitot tube. Reconnect the capillary tubing and position the pitot tube at the location of the last traverse measurement taken. Take the velocity pressure verification reading and record the location and velocity pressure reading in section 8 of the Velocity Measurement Input Form (Form 5-M). The stack readings are valid if the verification reading is within 5% of the last traverse reading.<br><br>**NOTE**: If the last air flow measurement appears unstable or unsuitably low because of the proximity to the stack wall, then another air flow measurement from another location must be verified. If the readings are not validated, void the log entries and repeat the measurement. |
| **Completing measurements** | |
| 24 | Determine the stack gas dry molecular weight. For processes emitting essentially air, use a dry molecular weight of 29.0. Record the gas dry molecular weight in section 9 of the Velocity Measurement Input Form (Form 5-M).<br><br>EXCEPTION: For combustion processes or processes that emit essentially $CO_2$, $O_2$, CO, and $N_2$, use EPA Reference Method 3 to determine the stack gas dry molecular weight. EPA Reference Method 3 is not covered in this procedure. |
| 25 | Record, in section 10 of the Velocity Measurement Input Form (Form 5-M), any condition(s) that may affect the accuracy or the validity of the measurement data. For example, erratic readings, negative velocity pressures, parallel and perpendicular to flow, etc. |

*Steps continued on next page.*

# Measuring flow, continued

| Step | Action |
|---|---|
| 26 | Plug the last hole. Record a check in the box in section 11 of the Velocity Measurement Input Form. |
| 27 | Record the time of the last reading in section 4 of the Velocity Measurement Input Form (Form 5-M). |
| 28 | Request an RCT to check all equipment for potential contamination. Follow all facility rules and RCT instructions for disposing of potentially contaminated PPE and supplies. |
| 29 | Inspect the work site to be sure all equipment and tools have been collected. |
| 30 | Depart facility, complying with all facility requirements as needed. Notify facility personnel that all measurements have been completed. |

# Post-measurement verifications

**Post-measurement verification of equipment**

Post-measurement verifications are required to verify that equipment was operating correctly during field measurements.

**Determine atmospheric pressure**

Determine the atmospheric pressure at the time of measurement from either the TA-6 tower barometer (see MAQ Weather Machine site) or the barometer at TA-35-34. Record the barometric pressure and the location of the barometer in section 12 of the Velocity Measurement Input Form (Form 5-M).

**NOTE**: This step may be completed at any time after the measurements by using the archive feature on the LANL weather machine.

**Maximum range of wind tunnel**

The wind tunnel at TA-35 has a maximum velocity of 3000 ft per minute (equivalent to about 0.75 inches of water). Any field readings over this value cannot be verified with the wind tunnel and should have been verified during the stack flow measurements using a second EDM.

**Verify EDM with wind tunnel**

If a manometer other than an oil-gage manometer was used (e.g., EDM), then a post-measurement verification must be performed. Use the wind tunnel at TA-35 to compare velocity pressure readings from the EDM to an oil-gage manometer (see next chapter *Using the Wind Tunnel*). Verify the readings at three different air velocities representing the approximate range of velocity pressure readings (high-mid-low) encountered in the field.

**Verify thermometer**

Verify the accuracy of the digital thermometer used by reading it against a calibrated mercury-in-glass thermometer at ambient temperature. The temperatures, in degrees Rankine, should not deviate more than 1.5% (e.g., 75°F ± 8°F). Record the verification information in section 13 of the Velocity Measurement Input Form (°R = °F + 460).

# Using the wind tunnel

**Instruments on the wind tunnel**

The wind tunnel located at TA-35 building 34 has a permanently installed pitot tube and a dedicated inclined manometer that is used to verify the accuracy of the measured velocity pressures. Both of these instruments are primary standards for velocity pressure measurements.

**Test wind tunnel performance**

When the EDM is recently returned from the calibration laboratory, perform a test on the wind tunnel and installed pitot tube by measuring the wind tunnel's flow rate with the fan on its maximum setting. Compare the measured value with the historical value for this fan and tunnel configuration. Investigate and resolve any differences.

**Steps to check EDM in wind tunnel**

To check the operation of the EDM , perform the following steps:

| Step | Action |
|---|---|
| 1 | **Warning:** The fan is noisy and hearing protection is advised, but not required.<br>Remove the inlet cover to the wind tunnel. Turn on the fan and adjust the dial on the wind tunnel controller to a velocity pressure near the stack velocity pressures measured on that day. Make sure the valves on top of the incline manometer are open by rotating the two valves counter clockwise one full turn. |
| 2 | Once the velocity pressure is set, connect the EDM used in that day's flow measurements to the pitot tube, in parallel with the incline manometer using the tubing on the incline manometer. When readings stabilize, compare the two instruments. The values should be within ±5% to pass the verification test. |
| 3 | Take a total of three measurements at velocity pressures approximating those measured at the stack on that day.<br>**Example**: If the approximate average stack velocity pressure is 0.50 inches, verification measurements could be taken at 0.35 inches, 0.50 inches, and 0.75 inches. |
| 4 | Record the test results in section 13 of the Velocity Measurement Input Form (Form 5M). If the oil-gage manometer readings deviate more than ±5% from the instrument that was used in the field, the flow measurements must be repeated. |
| 5 | Repeat the above 2 steps at all required velocity pressure ranges. |
| 6 | After all measurements have been completed, close the valves on the incline manometer, turn off the wind tunnel, and replace the inlet cover to the wind tunnel. |

# Downloading data

**Downloading data**

The TSI micromanometer has the capability of storing field collected data and downloading it into the STACKS database. This minimizes the possibility of transcription errors of manually entered data into the database. Follow the steps below to import the velocity pressure measurements into the STACKS database.

**Steps to download data**

To download the data, perform the following steps:

| Step | Action |
|---|---|
| 1 | Ensure the computer that is to be used for data downloads is properly equipped with the appropriate hardware to connect the TSI to the computer. Also ensure the computer has the "LOGDAT" software installed. If the computer is not properly set up, contact computer support personnel for assistance. |
| 2 | Connect one end of the TSI-supplied computer interface cable to a computer serial port and the other end to the TSI micromanometer. |
| 3 | Locate the "LOGDAT" program on the computer and start the program. Click on the "download" button and follow the directions on the computer screen. When asked to select a file to save the data, select an appropriate name and file location so that it can be easily retrieved. Select the correct com port where the interface cable has been connected and verify the baud rate of the TSI and the baud rate of the program are the same. Continue to follow the computer directions until downloading is completed. |
| 4 | Locate and open the .DAT file that was created in step 3 using Excel. Also locate and open the "Profiles" folder in the Rad-NESHAPs folder of the Projects drive. Referring back to the raw data sheets, open the appropriate Excel profile form for the measured system (e.g., 2 x 12, 3 x 12, 5 x 5, etc.). |
| 5 | In Excel, cut only the velocity pressure data from the data file and paste the data into the appropriate Excel profile form. Save the profile form to a temporary folder using the system ID number as the file name. Repeat this step if multiple systems were measured during the test day. |
| 6 | Open the "STACKS" database and create a Form 5M for the measured exhaust stack. Input all system and equipment data into Form 5M from the raw data sheets. |

*Steps continued on next page.*

# **Downloading data**, continued

| Step | Action |
|---|---|
| 7 | Select the "Import velocity pressures" button. Indicate the location and name of the velocity pressure data file that was created in step 5. Average velocity pressures will automatically be imported into the database. Save the velocity measurement input form and return to Form 5M. |
| 8 | Input the remaining information into Access version of Form 5M. |
| 9 | Click on the "individual velocities" button and print a copy. Review the printout for completeness and sign the individual velocity form. |
| 10 | Attach this form to the raw data sheets or the transcribed data sheets and forward this information to the MAQ QA reviewer for QA review. If the original field data forms are transcribed to achieve a clean record copy, attach the original field data forms to the transcribed copy and submit both copies. |
| 11 | Disconnect the TSI from the computer. Clear all data stored in the TSI by holding the "clear" button until the countdown reaches 0. The display will flash "CLr". All data points have now been deleted and the TSI is ready for the next test day. |

# Verifying data and performing calculations

**Verify data collection**

The **MAQ QA reviewer** inspects the data package to ensure all appropriate QA documentation has been included. This includes verifying that the appropriate data have been properly recorded and all values are within the expected range for that parameter.

**Reviewing data and calculations**

The **MAQ QA reviewer** performs a 10% independent verification on the electronically transferred data into the "Stacks" database to ensure the data have been transferred correctly. Document this review of the data on Attachment 7 ("Stack Flow Data Transcription and Electronic Verification Form") by checking column 2 and signing.

The **MAQ QA reviewer** also verifies 100% of the hand-entered data from Form 5M into the "STACKS" database. Check the box in STACKS database to indicate this verification.

**Reviewing calculations**

An assigned **MAQ QA reviewer** reviews the data package to verify all parameters have been entered correctly into the STACK database. The **QA reviewer** also verifies that the "STACKS" database printout accurately reflects the raw data forms. The **QA reviewer** documents the review by initialing the forms and signing the bottom of the "Stacks" output form. The QA reviewer must also perform and approve the electronic version of the data package in the "Stacks" database. When all reviews have been completed, Sign form 6 of STACKS database printout to indicate acceptance of the data package and forward the final data package to the MAQ Engineer.

**Checking airflow calculation program**

If the computer program is not available to calculate airflows, or as a check on the computer program, an **MAQ Engineer** (or other qualified individual) performs flow measurement calculations manually by following the steps below and using the Flow Measurement Calculation Form (Form 6) to document the results. Carry out calculations retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation. After calculation, enter the data into the MAQ "Stacks" database.

# Verifying data and performing calculations, continued

**Calculation nomenclature**

The following terms are used in flow measurement calculations:

A = Cross-sectional area of the stack or duct, $ft^2$.
$B_{ws}$ = Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume. Use a value of 0% relative humidity for conservatism.
$C_p$ = Pitot tube coefficient, dimensionless.
$K_p$ = Pitot tube constant,

$$85.49 \frac{\text{ft}}{\text{sec}} \left[ \frac{\text{lb/ lb- mole) (in.Hg)}}{(^\circ\text{R}) \ (\text{in.H}_2\text{O})} \right]^{1/2}$$

$M_d$ = Molecular weight of stack gas, dry basis, lb/lb-mole.
$M_s$ = Molecular weight of stack gas, wet basis, lb/lb-mole.

$$= M_d (1 - B_{ws}) + 18.0 B_{ws} \qquad \text{Note: } (B_{ws} = 0)$$

$P_{bar}$ = Barometric pressure at measurement site, in. Hg.
$P_g$ = Stack static pressure, in. Hg.
$P_{ref}$ = Barometric pressure at reference barometer, inches Hg.
$P_s$ = Absolute stack pressure, in. Hg,

$$P_s = P_{bar} + P_g$$

**Calculation nomenclature**, *continued*

$P_{std}$ = Standard absolute pressure, 29.92 in. Hg.
$Q_{sd}$ = Dry volumetric stack gas flow rate corrected to standard conditions, dscf/hr.
$t_s$ = Stack temperature, °F.
$T_s$ = Absolute stack temperature, °R.

$$^\circ R = 460 + t_s$$

$T_{std}$ = Standard absolute temperature, 528°R.
$v_s$ = Average stack gas velocity, ft/min.
$\Delta p$ = Velocity head of stack gas, in. $H_20$.
3,600 = Conversion factor, sec/hr.
18.0 = Molecular weight of water, lb/lb-mole.

# Verifying data and performing calculations, continued

**Steps to perform calculations**

To perform flow measurement calculations, perform the following steps:

| Step | Action |
|---|---|
| 1 | From the field input form, calculate the average stack gas temperature. The average stack gas temperature is: $$t_{s(avg)} = \frac{\sum_{i=1}^{n} t_i}{n}$$ where "n" is the number of measurement points. The exhaust stack average absolute temperature is: $$T_{s(avg)} = 460 + t_{s(avg)} \quad \text{for English}$$ |
| 2 | The exhaust stack absolute pressure is given by: $$P_s = P_{bar} + P_g \quad \text{inches Hg}$$ where, corrected for elevation, the barometric pressure at the measurement site is: $$P_{bar} = P_{ref} + \left(Elevation_{profile} - Elevation_{ref}\right)\left(\frac{-0.1''\,Hg}{100\,ft}\right) \quad \text{inches Hg}$$ and the stack gas pressure (static pressure) is $$P_g = P_g''wg\left(\frac{62.4}{846.9}\right) \quad \text{inches Hg}$$ |
| 3 | The molecular weight of the gas, wet basis, is given by: $$M_s = M_d(1 - B_{ws}) + 18.0\,B_{ws} \qquad \textbf{Note}: (B_{ws} = 0)$$ Assuming relatively dry air, the molecular weight of the gas, wet basis, reduces to the molecular weight of the stack gas, dry basis, which is: $M_d$ = Molecular weight of stack gas, dry basis, lb/lb-mole. For processes <u>emitting essentially dry air</u>, use: $$M_s = M_d = 29.0 \text{ lb/lb-mole}$$ |

*Steps continued on next page.*

# **Verifying data and performing calculations**, continued

| Step | Action |
|---|---|
| 4 | Determine K from the following: $$K = K_p \left( \frac{60\,\text{sec}}{\text{min}} \right) \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$ $$\text{where } K_p = 85.49 \frac{\text{ft}}{\text{sec}} \left[ \frac{(\text{lb/ lb-mole})\ (\text{in. Hg})}{(^\circ \text{R})\ (\text{in. } H_2O)} \right]^{1/2}$$ |
| 5 | From the field input form, calculate the average velocity head of the stack gas. The average velocity head is: $$(\sqrt{\Delta p})_{(avg)} = \frac{\sum_{i=1}^{n} \sqrt{\Delta p}}{n}$$ |
| 6 | Calculate the average stack gas velocity (actual): $$v_s = C_p\, K\ (\sqrt{\Delta p})_{avg} \quad \text{ft/min}$$ |
| 7 | Calculate the exhaust stack flow rate (actual): $$Q_{sd} = v_s A \quad \text{acfm}$$ |
| 8 | Calculate the average stack gas dry volumetric flow rate: $$Q_{sd} = (1 - B_{ws})\, v_s A\ \frac{T_{std}}{T_{s(avg)}}\ \frac{P_s}{P_{std}} \quad \text{scfm}$$ |

# Reviewing and verifying calculations

**Review and verify calculations**

The **MAQ engineer** receives the data package (original data forms, final velocity and volumetric flow rate calculations, and all supporting documentation) and performs a detailed review and verification of the data. This review includes the accuracy of the measured data, trends in the total volumetric airflow rate, isokinetic checks, and various verification checks. Initial Form 5M to indicate approval of data and calculation results. Indicate approval in the STACKS database by checking the verification box.

**Submit records**

The **MAQ engineer** forwards the original forms to the Group Office for photocopying. After copying, file the official data package in the MAQ Records Center and the Xerox copy in the Rad-NESHAP working files room.

**Update the database**

The **MAQ engineer** updates the STACKS database when any changes occur to the stack flow measurement equipment or the ventilation system (e.g., calibration, new equipment, stack diameter, measurement matrix, etc.).

# Records resulting from this procedure

**Records**

The following records generated as a result of this procedure are to be submitted as records **within two weeks of completion** to the group records coordinator:

- Attachment 3, Velocity Measurement Input Form (Form 5-M)
- Attachment 8 [Flow Measurement Calculation Form (Form 6)] or computer output of flow measurement calculations
- At least one of the following forms, as appropriate:
  - Attachment 4 [Velocity Measurement Input Form (2 x 12 Round Stack or Duct) (Form 5-R)]
  - Attachment 5 [Velocity Measurement Input Form (6 x 5 Rectangular Stack or Duct) (Form 5-S)]
  - Attachment 6 [Velocity Measurement Input Continuation Form (Form 5-C)]
- Attachment 7 (Stack Flow Data Transcription and Entry Verification Form)
- One of the following forms, when a new measurement location is selected:
  - Attachment 9 [Cross-Sectional Area Worksheet (Round Exhaust Stack/Duct) (Form 7-R)]
  - Attachment 10 [Cross-Sectional Area Worksheet (Rectangular Exhaust Stack/Duct) (Form 7-S)]

# HAZARD CONTROL PLAN

1. The work to be performed is described in this procedure.

**"Determination of Stack Gas Velocity and Flow rate in Exhaust Stacks, Ducts, and Vents"**

2. Describe potential hazards associated with the work (use continuation page if needed).

a) Radiological hazards - Potiental contamination from contact with port plugs, pitot tubes, and other equipment that is inserted into the exhaust stack of duct. Radiological hazards may also be present from work in radiologically controlled areas.
b) hand tools - nicks, cuts, bruises from using tools.
c) Work at elevation (ladders, scaffolding, bucket truck) - slips & falls from equipment
d) General work area hazards - uneven flooring, noise, low headroom, cramped conditions
e) Facility-specific hazards - Emergency response
f) Over head work – Potential of falling objects.
g) Stack air - Workers may be exposed to pollutants in stack (rad, non-rad, chemicals) while measurement ports are open.
h) Rotating Machinery – Work will be performed in mechanical rooms and near exhaust fans.
i) Weather – Heat exposure, cold weather, wind, lighting, rain
j) Compressed Air – Potential for compressed air canister to bust or rupture.
k) Noise from wind tunnel and mechanical equipment --When running, the wind tunnel produces some noise, but levels are well below levels that require hearing protection. Other facility areas may have hearing protection requirements.

3. For each hazard, list the likelihood and severity, and the resulting initial risk level (before any work controls are applied, as determined according to LIR300-00-01, section 7.2)

a) Radiological hazards - (all) frequent / negligible = Low
b) hand tools - occasional / moderate = Low
c) work at elevation (ladders, scaffolding, bucket truck) - occasional / moderate = Low
d) General work area hazards: occasional / moderate = Low
e) Facility-specific hazards: occasional / moderate = Low
f) Overhead Work - occasional / moderate = Low
g) Stack air exposure: occasional / moderate = Low
h) Rotating Machinery – occasional / moderate = Low
i) Weather – occasional / moderate = Low

Overall initial risk: ☐ Minimal ☒ Low ☐ Medium ☐ High

4. Applicable Laboratory, facility, or activity operational requirements directly related to the work:

☐ None ☒ List: Work Permits required? ☐ No ☒ List:

LIR-402-706-01 "Personnel Dosimetry"
Radiological work permit may be required for work that is performed inside the exhaust stack. Consult with facility HSR-1 team before performing stack flow measurements to ensure facility-specific radiological requirements have not changed. Other facility-specific requirements may apply for some locations. Contact FMU operations.

## HAZARD CONTROL PLAN, continued

5. Describe how the hazards listed above will be mitigated (e.g., safety equipment, administrative controls, etc.):

a) Rad hazards: Rad-Worker II training, obey all postings, minimize time in any radiological area. Wear rubber gloves whenever in contact with equipment that has been inside the exhaust stack or duct.
b) Hand tools: work in a calm, unhurried manner. Wear leather gloves as needed.
c) Ladders/Scaffolding/Bucket Truck: Take required training (see item 6). Wear closed-toe footwear with non-slip soles when climbing ladders or scaffolding. When climbing, keep hands free of any items. Transport work items to working platform by means of a back pack or lift & lower with container and rope, as appropriate. Learn the weight limit of the scaffold & ensure it is not exceeded. When working from bucket, ensure you wear the appropriate fall protection harness and do not over-reach and keep arms inside the bucket while it is being moved.
This procedure requires two people minimum for all work in facilities.
See continuation page.

6. Knowledge, skills, abilities, and training necessary to safely perform this work (check one or both):

☒ Group-level orientation (per MAQ-032) and training to this procedure.

☒ Other → See training prerequisites on procedure page 3. Any additional describe here:

Rad Worker training. Facility-specific training.
Scaffolding Training or Ladder Safety for airflow measurements that requires the work to be performed from elevated surfaces.
For airflow measurements that require a bucket truck: training course #13079 Basic Fall Protection.

7. Any wastes and/or residual materials? (check one) ☒ None ☐ List:
PPE and HSR-1 materials (used to survey equipment for release) to be disposed of by facility personnel.

8. Considering the administrative and engineering controls to be used, the *residual* risk level (as determined according to LIR300-00-01, section 7.3.3) is (check one):

☐ Minimal ☒ Low ☐ Medium (requires approval by Division Director)

9. Emergency actions to take in event of control failures or abnormal operation (check one):

☐ None ☒ List:

For all injuries, provide first aid and see that injured person is taken to Occupation Medicine (for minor injuries and follow-up) or the hospital (if immediate medical attention is required). Notify the Operations manager of the injury. For any exposed, energized electrical wires, contact KSL or the appropriate authority to turn off the power. Follow all site specific emergency plans for any radiation or other emergencies.

Signature of preparer of this HCP: This HCP was prepared by a knowledgeable individual and reviewed in accordance with requirements in LIR 300-00-01 and LIR 300-00-02.

__________________________ __________________________ ____________
Preparer(s) signature(s) Name(s) (print) /Position Date

Signature by group leader on procedure title page signifies authorization to perform work for personnel properly trained to this procedure. This authorization will be renewed annually and documented in MAQ records. Controlled copies are considered authorized. Work will be performed to controlled copies only. This plan and procedure will be revised according to MAQ-022 and distributed according to MAQ-030.

## **HAZARD CONTROL PLAN**, continued

**Hazard Control Plan continuation page. Give item number being continued.**

#3) Initial Risk Level:
j) Compressed Air - occasional / moderate = low
k) noise from wind tunnel -- occasional / moderate = low

# 5. How hazards are Mitigated:

d) Work area hazards: work in a calm, unhurried manner.
e) Facility-specific hazards: Have appropriate training, or be under escort by a qualified worker.
f) Overhead work: Requirements when work is being conducted at elevation (e.g., on scaffolding)

- All workers near scaffolding will wear hard hats and safety shoes when work is going on above.
- Keep all non-participants outside of the "cone of danger" by controlling access to work area.
- Secure equipment on the scaffolding or store in a container that is secured to the scaffolding.
- Workers on the ground shall remain outside the cone of danger during activities on the scaffolding or the bucket truck, unless actively assisting with hoisting or lowering.

g) Stack air: consult with HSR-1 (rad) and facility operations (non-rad & chemicals) to determine if special controls or PPE should be used during air flow measurement work
h) Rotating Machinery: Keep safe distance from moving parts. Ensure all rotating equipment have adequate guarding.
i) Weather: Wear appropriate clothing for the climate. Wear hats, sunscreen and long sleeve shirts to avoid sunburn. Apply the 30/30 rule for situations where there is evidence of an approaching lightning storm. Do not perform measurements under high wind conditions (25 mph, sustained)
j) Compressed Air: Handle compressed air canister in a manner to avoid damaging the can. Ensure canister is not trapped under other equipment where it could be punctured.
k) Noise: Use hearing protection (recommended) if working for more than a few minutes around operating wind tunnel or other high noise sources.

## Exhaust Stack Air Flow Measurement Schedule

| ESIDNUM TA/Bldg/ES | Profile Number | Configuration Number | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03002914 | 04 | 02 | X | | | | | | X | | | | | |
| 03002915 | 05 | 01 | X | | | | | | X | | | | | |
| 03002919 | 04 | 01 | X | | | | | | X | | | | | |
| 03002920 | 04 | 01 | X | | | | | | X | | | | | |
| 03002923 | 04 | 01 | X | | | | | | X | | | | | |
| 03002924 | 04 | 01 | X | | | | | | X | | | | | |
| 03002928 | 04 | 01 | X | | | | | | X | | | | | |
| 03002929 | 04 | 01 | X | | | | | | X | | | | | |
| 03002932 | 04 | 01 | X | | | | | | X | | | | | |
| 03002933 | 05 | 01 | X | | | | | | X | | | | | |
| 03002937 | 02 | 01 | | X | | | | | | X | | | X | |
| 03002944 | 03 | 02 | | X | | | X | | | X | | | X | |
| 03002945 | 03 | 02 | | X | | | X | | | X | | | X | |
| 03002945 | 03 | 02-QA | | | | | | | | Φ | | | | |
| 03002946 | 03 | 02 | | X | | | X | | | X | | | X | |
| 03010222 | 02 | 01 | | X | | | | | | X | | | X | |
| 03014101 | 01 | 01 | | | X | | | | | | X | | | |
| 03014101 | 01 | 02 | | | X | | | | | | X | | | |
| 03014101 | 01 | RRES-BM | | | Φ | | | | | | | | | |
| 16020504 | 04 | 02 | | | | | X | | | | | | X | |
| 21015505 | 01 | 01 | | | | | | ✪ | | | | | | ✪ |
| 21020901 | 03 | 01 | | | | | | ✪ | | | | | | ✪ |
| 48000107 | 01 | 01 | | | | | | X | | | | | | X |
| 48000107 | 01 | 02 | | | | | | X | | | | | | X |
| 48000154 | 01 | 01 | | | | | | ✪ | | | | | | ✪ |
| 48000160 | 02 | 01 | | | | | | X | | | | | | X |
| 50000102 | 03 | 01 | X | | | | | | X | | | | | |
| 50003701 | 03 | 01 | X | | | | | | X | | | | | |
| 50006903 | 01 | 01 | X | | | | | | X | | | | | |
| 53000303 | 2P | 9P | X | | | | | | X | | | | | |
| 53000702 | 05 | 02 | X | | | | | | X | | | | | |
| 53000702 | 05 | 07 | X | | | | | | X | | | | | |
| 55000415 | 01 | 01 | | | | | X | | | | | | X | |
| 55000416 | 01 | 01 | | | | | X | | | | | | X | |

## Exhaust Stack Air Flow Measurement Schedule

| ESIDNUM TA/Bldg/ES | Profile Number | Configuration Number | **January** | **February** | **March** | **April** | **May** | **June** | **July** | **August** | **September** | **October** | **November** | **December** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Φ Duplicate flow measurement for quality assurance purposes

✪ Stack flow measurement requiring the use of a bucket truck and performed on same day

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## Velocity Measurement Input Form (Form 5-M)

Page 1 of 2 | This form is from MAQ-127

TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

FE(s) _____________

Profile Measurement Number _________ Fan Exhaust Configuration _________

☐ Quarterly/Semi-annual airflow measurement ☐ Special Measurement ☐ Other:____________

☐ Method 2 (stack or duct diameter ≥ 12 inches) or ☐ Method 2C (stack or duct diameter ≥ 4 inches but < 12 inches)

**1. Equipment used and verification**

Manometer ____________ Serial Number ____________ Calibration Expiration ____/____/____

Thermometer ____________ Serial Number ____________ Calibration Expiration ____/____/____



Humidity Meter ____________ Serial Number ____________ Calibration Expiration ____/____/____

Pitot Tube ____________ Serial Number ____________

☐ Traverse spacing pre-marked on pitot tube / pitot tube inspected

**2. Location inspection**

Location Comments: ________________________________________________

**3. Equipment setup**

☐ Zero the manometer ΔP offset ___________

☐ Connect manometer to tubing ☐ Adjust manometer sensitivity

Pre-test leak check performed (not mandatory): ☐ Yes ☐ No

**4. Perform traverse readings** (record velocity pressure and temperature in table on appropriate form)

Run Start Time:__________ Run Complete Time:__________ Average Temperature___________

**5. Diameter and cross-sectional area of stack or duct (from previous measurements)**

Diameter: ___________ (in.) Dimensions: ____________ (in.) Area: _____________ (sq feet)

**6. Post measurement leak test (3" wg)**

☐ successful ☐ measurement voided

**7. Static Pressure and Relative Humidity**

SP=____________ (" $H_2O$) RH=______________%

**8. Back purge standard pitot tube and verify** ☐ Not required

Profile location ____________ Reading _________ (in wg) Percent difference ________ %

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## Velocity Measurement Input Form (Form 5-M), continued

Page 2 of 2 | This form is from MAQ-127

**9. Stack gas dry molecular weight**

☐ Reference Method 3 ___________ ☐ Room Air (Use 29.0)

**10. Condition which might affect measurements**

______________________________________________________________

**11. Holes covered**

☐ Complete

**12. Atmospheric Pressure**

_____________ ("Hg) Barometer Location _______________________

**13. Post Measurement Verifications**

☐ Manometer verification passed (within 5%) ☐ Manometer verification not required.



| Test Number | Velocity Pressure (inches | | |
|---|---|---|---|
| | Manometer | Reference | % Difference |
| 1 | | | |
| 2 | | | |
| 3 | | | |

☐ Thermometer verification passed (within 1.5%)

| Temperature Reading °F | | Absolute Temperature °R | | |
|---|---|---|---|---|
| | | °R = °F + 460 | | |
| Thermometer | Reference | Thermometer | Reference | % Difference |
| | | | | |

Comments:

Flow measurements were made in accordance with the latest revision of MAQ-127.
Measurements by:

____________________ ___________________________ ________________ _____/_____/_____
Signature Print name Z-Number Date

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

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# Velocity Measurement Input Form (Form 5-R)

## (2 x 12 Round Stack or Duct)

Page 1 of 1

This form is from MAQ-127

TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

| Measurement Traverse A | | | | Measurement Traverse B | | | |
|---|---|---|---|---|---|---|---|
| Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) | Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) |
| A1 | | | | B1 | | | |
| A2 | | | | B2 | | | |
| A3 | | | | B3 | | | |
| A4 | | | | B4 | | | |
| A5 | | | | B5 | | | |
| A6 | | | | B6 | | | |
| A7 | | | | B7 | | | |
| A8 | | | | B8 | | | |
| A9 | | | | B9 | | | |
| A10 | | | | B10 | | | |
| A11 | | | | B11 | | | |
| A12 | | | | B12 | | | |

Measurements by:

Signature ____________ Print name ____________ Z-Number ____________ Date ______/______/______

MAQ QA check by (initials):

MAQ review and approval by (initials):

**Meteorology and Air Quality**

# Velocity Measurement Input Form (Form 5-S)

## (6 x 5 Rectangular Stack or Duct)

Page 1 of 1

This form is from MAQ-127

TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

| Measurement Traverse A | | | | Measurement Traverse B | | | |
|---|---|---|---|---|---|---|---|
| Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) | Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) |
| A1 | | | | D1 | | | |
| A2 | | | | D2 | | | |
| A3 | | | | D3 | | | |
| A4 | | | | D4 | | | |
| A5 | | | | D | | | |
| | | | | | | | |
| B1 | | | | 1 | | | |
| B2 | | | | E2 | | | |
| B3 | | | | E3 | | | |
| B4 | | | | E4 | | | |
| B5 | | | | E5 | | | |
| | | | | | | | |
| C1 | | | | F1 | | | |
| C2 | | | | F2 | | | |
| C3 | | | | F3 | | | |
| C4 | | | | F4 | | | |
| C5 | | | | F5 | | | |



Measurements by:

____________________ Signature
__________________________ Print name
________________ Z-Number
_____/_____/_____ Date

MAQ QA check by (initials):

MAQ review and approval by (initials):

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# Velocity Measurement Input Continuation Form (Form 5-C)

Page 1 of 1 This form is from MAQ-127

TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

| Measurement Traverse ____ | | | | Measurement Traverse ____ | | | |
|---|---|---|---|---|---|---|---|
| Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) | Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) |
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Measurements by:

____________________ Signature ____________________ Print name ________________ Z-Number ______/______/______ Date

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|
| | |

Meteorology and Air Quality

# Stack Flow Data Transcription and Entry Verification Form

Page 1 of 1 This form is from MAQ-127

Place check in appropriate column:
**Column 1**: Data transcription verification **Column 2**: Data entry verification

| 1 | 2 | Stack ID | 1 | 2 | Stack ID |
|---|---|---|---|---|---|
| | | TA-03, bldg-0029, ES-14, config. # 02 | | | TA-41, bldg-0004, ES-17, config. #01 |
| | | TA-03, bldg-0029, ES-15, config. # 01 | | | TA-48, bldg-0001, ES-07, config. # 01 |
| | | TA-03, bldg-0029, ES-19, config. # 01 | | | TA-48, bldg-0001, ES-07, config. # 02 |
| | | TA-03, bldg-0029, ES-20, config. # 01 | | | TA-48, bldg-0001, ES-54, config. # 01 |
| | | TA-03, bldg-0029, ES-23, config. # 01 | | | TA-48, bldg-0001, ES-60, config. # 01 |
| | | TA-03, bldg-0029, ES-24, config. # 01 | | | TA-50, bldg-0001, ES-02, config. # 01 |
| | | TA-03, bldg-0029, ES-28, config. # 01 | | | TA-50, bldg-0037, ES-01, config. # 01 |
| | | TA-03, bldg-0029, ES-29, config. # 01 | | | TA-50, bldg-0069, ES-03, config. # 01 |
| | | TA-03, bldg-0029, ES-32, config. # 01 | | | TA-53, bldg-0003, ES-03, config. # |
| | | TA-03, bl[illegible]-0029, ES-33, [illegible]g. # 0[illegible] | | | TA-[illegible] bl[illegible]-0003, ES[illegible]3, config. # |
| | | TA-03, bld[illegible]029, ES-37 [illegible]con[illegible]g. # 0[illegible] | | | TA-[illegible], b[illegible]g-0003, E[illegible]fig. # |
| | | TA-03, bldg-002[illegible] ES-[illegible]. # [illegible] | | | TA-53, b[illegible]g-0003, E[illegible]03, config. # |
| | | TA-03, b[illegible] 002[illegible] ES[illegible]5, con[illegible] #[illegible] | | | TA-53, [illegible]-0007, E[illegible]fig. # |
| | | TA-03, bldg-0029, ES-46, config. # 02 | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-03, bldg-0102, ES-22, config. # 01 | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-03, bldg-0141, ES-01, config. # 01 | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-03, bldg-0141, ES-01, config. # 02 | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-16, bldg-0205, ES-04, config. # 02 | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-21, bldg-0155, ES-05, config. # 01 | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-21, bldg-0209, ES-01, config. # 01 | | | TA-55, bldg-0004, ES-15, config. # 01 |
| | | TA-33, bldg-0086, ES-06, config. # 01 | | | TA-55, bldg-0004, ES-16, config. # 01 |
| | | TA-33, bldg-0086, ES-06, config. # 02 | | | |
| | | TA-33, bldg-0086, ES-06, config. # 03 | | | |
| | | | | | |



For the stacks checked above in **column 1**, I have performed a 100% verification to ensure the data have been **transcribed** correctly from the "raw" data forms to the "official" records form. The parameters verified are the duct static pressure, cross-sectional area of the duct/stack, atmospheric pressure, temperature of air in the stack, and the velocity pressure readings.

________________ ________________ ________________ ____/____/____
Signature Print name Z-Number Date

For the stacks checked above in **column 2**, I have performed a100% verification on all hand entered information to ensure the **data entered** into the "Stack" database corresponds to the data collected in the field. The parameters verified are the duct static pressure, cross-sectional area of the duct/stack, atmospheric pressure and temperature of air in the stack. Furthermore, I have performed a 10% verification on all electronically transferred information into the "Stacks" database to ensure the data corresponds with that collected in the field. The parameters verified are the velocity pressure readings.

________________ ________________ ________________ ____/____/____
Signature Print name Z-Number Date

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# Flow Measurement Calculation Form (Form 6)

Page 1 of 2 This form is from MAQ-127

TA/Building/ES ______-______-______ FE(s) ________________________

Measurement Date _____/_____/_____ Fan Exhaust Configuration _________

Profile Measurement Number _________

**Step 1: Calculate the stack gas average absolute temperature, $T_{s(avg)}$**

a) From field input form, determine $t_{s(avg)}$ = _________ °F

b) Calculate the absolute temperature, $T_{s(avg)} = t_{s(avg)} + 460$ = ________ °R

**Step 2: Calculate the exhaust stack absolute pressure, $P_s$**

a) From the field input form, record the barometric reference pressure, $P_{ref}$ = _________ " Hg

b) Adjust for elevation



= $P_{ref}$ + [Elevation $_{prof}$ – Elevation $_{ref}$] (-0.1 "Hg / 100 ft)

= ________ "Hg + [__________ ft – __________ ft] (-0.1/100)

= _____________ "Hg

c) From the field input form, record the stack static pressure, $P_g$ = __________ " wg

d) Convert the static pressure from inches w.g. to inches Hg

$P_g$ = [$P_g$ "wg] (62.4 / 846.9) "Hg

= __________ (62.4 / 846.9) "Hg

= __________ "Hg

e) Calculate the exhaust stack absolute pressure

$P_s = P_{bar} + P_g$

= ________ + ________ = ________ "Hg

**Step 3: Calculate the molecular weight of the stack gas, $M_s$**

a) From Method 4 or 5 $B_{ws}$ = __________ (**Always** use 0 for conservatism)

b) From Method 3 $M_d$ = __________ (Use 29 for air)

c) Calculate $M_s$ $M_s = M_d (1 - B_{ws}) + 18.0 B_{ws}$

= ________ ( 1 - ________ ) + 18.0 ( ________ )

= ________ lb / lb mole

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## Flow Measurement Calculation Form (Form 6), continued



This form is from MAQ-127

**Step 4: Calculate K**

a) K = (85.49) (60) SQRT[ $T_{s(avg)}$ / $P_sM_s$ ]

= (85.49)(60) SQRT [ ________ / (________)(________)] = ____________

**Step 5: From the field input form, calculate the average velocity head of the stack gas**

a) $(\sqrt{\Delta p})_{(avg)} = \dfrac{\sum_{i=1}^{n} \sqrt{\Delta p}}{n}$ = __________ inches water

**Step 6: Calculate the average stack gas velocity (actual), $v_s$**

a) $C_p$ K $(\sqrt{\Delta p})_{avg}$ n

= ________ * ________

________ ft/min



**Step 7: Calculate the exhaust stack flow rate (actual), Q**

a) Record the stack/duct cross-sectional area from profile measurements

A = __________ $ft^2$

b) Q = $v_s$ * A

= ________ * ________

= ________ acfm

**Step 8: Calculate the exhaust stack gas dry volumetric flow rate (standard), Qsd**

a) $Q_{sd} = (1 - B_{ws})\, v_s A \dfrac{T_{std}}{T_{s(avg)}} \dfrac{P_s}{P_{std}}$

$Q_{sd}$ = [ 1 - ________ ] * ________ * ________ [ ________ / ________ ] [ ________ / ________ ]

$Q_{sd}$ = ____________ scfm

Calculations by:

| Signature | Print name | Z-Number | Date ____/____/____ |
|---|---|---|---|

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

Meteorology and Air Quality

# Cross-Sectional Area Worksheet (Round Exhaust Stack or Duct) (Form 7-R)

Page 1 of 1 This form is from MAQ-127

TA/Building/ES ______-______-______ FE(s) ________________________

Profile Measurement Number __________

**1. Sketch the exhaust stack or duct cross- section and label the traverses. Include any references in the sketch.**

SAMPLE

**2. Measure the diameters to the nearest 1/8 inch**

| Traverse Number | Measured Diameter (nearest 1/8”) | Diameter (decimal format in inches) |
|---|---|---|
| $d_1$ | | |
| $d_2$ | | |
| $d_3$ | | |
| $d_4$ | | |

Measurements by:

| ____________________ | __________________________ | ________________ | _____/_____/_____ |
|---|---|---|---|
| Signature | Print name | Z-Number | Date |

**3. Calculate the cross- sectional area. Do not round d or π . Round final number to three decimal places.**

Round: $Area = \pi\left[\frac{d}{2}\right]^2\left[\frac{1}{144}\right]$ **OR** Oval: $Area = \frac{\pi * d_1 * d_2}{576}$ Area = ________________ sq feet

Calculations by:

| ____________________ | __________________________ | ________________ | _____/_____/_____ |
|---|---|---|---|
| Signature | Print name | Z-Number | Date |

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

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# Cross-Sectional Area Worksheet (Rectangular Exhaust Stack or Duct) (Form 7-S)

Page 1 of 1 — This form is from MAQ-127

TA/Building/ES ______-______-______ FE(s) ________________________

Profile Measurement Number _________

**1. Sketch the exhaust stack or duct cross- section and label the traverses. Include any references in the sketch.**



**2. Measure the widths and depths to the nearest 1/8 inch**

| Traverse Number | Measured Diameter (nearest 1/8”) | Diameter (decimal format in inches) |
|---|---|---|
| Width 1 (W1) | | |
| Width 2 (W2) | | |
| Depth 1 (D1) | | |
| Depth 2 (D2) | | |

Measurements by:

____________________ ____________________ ____________________ _____/_____/_____
Signature Print name Z-Number Date

**3. Calculate the cross- sectional area. Round final number to three decimal places.**

$$Area = \left[\frac{W1+W2}{2}\right]\left[\frac{D1+D2}{2}\right]\left[\frac{1}{144}\right] \text{ sq feet}$$

Area = _________________ sq feet

Calculations Performed by:

____________________ ____________________ ____________________ _____/_____/_____
Signature Print name Z-Number Date

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

Meteorology and Air Quality

# Velocity Measurement Input Form (Form 5-M)



This form is from MAQ-127

TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

FE(s) _____________

Profile Measurement Number _________ Fan Exhaust Configuration _________

☐ Periodic airflow measurement ☐ Special Measurement ☐ Other:____________________

☐ Method 2 (stack or duct diameter ≥ 12 inches) or ☐ Method 2C (stack or duct diameter ≥ 4 inches but < 12 inches)

**1. Equipment used and verification**

Manometer ____________ Serial Number ____________ Calibration Expiration ____/____/____

Thermometer __________ Serial Number ____________ Calibration Expiration ____/____/____

Humidity Meter__________ Serial Number ____________ Calibration Expiration ____/____/____

Pitot Tube ____________ Serial Number ____________

☐ Traverse spacing pre-marked on pitot tube / pitot tube inspected

**2. Location inspection**

Location Comments: ______________________________________________________

**3. Equipment setup**

☐ Zero the manometer ΔP offset ___________

☐ Connect manometer to tubing ☐ Adjust manometer sensitivity

Pre-test leak check performed (not mandatory): ☐ Yes ☐ No

**4. Perform traverse readings** (record velocity pressure and temperature in table on appropriate form)

Run Start Time:__________ Run Complete Time:__________ Average Temperature___________

**5. Diameter and cross-sectional area of stack or duct (from previous measurements)**

Diameter: ___________ (in.) Dimensions: ________________ (in.) Area: _____________ (sq feet)

**6. Post measurement leak test (3” wg)**

☐ successful ☐ measurement voided

**7. Static Pressure and Relative Humidity**

SP=____________ (” $H_2O$) RH=______________%

**8. Back purge standard pitot tube and verify** ☐ Not required

Profile location ____________ Reading _________ (in wg) Percent difference ________ %

# Velocity Measurement Input Form (Form 5-M), continued





**9. Stack gas dry molecular weight**

☐ Reference Method 3 ___________ ☐ Room Air (Use 29.0)

**10. Condition which might affect measurements**

______________________________________________________________________

**11. Holes covered**

☐ Complete

**12. Atmospheric Pressure**

_____________ ("Hg) Barometer Location ______________________

**13. Post Measurement Verifications**

☐ Manometer verification passed (within 5%) ☐ Manometer verification not required.

| Test Number | Velocity Pressure (inches wg) | | |
|---|---|---|---|
| | Manometer | Reference | % Difference |
| 1 | | | |
| 2 | | | |
| 3 | | | |

☐ Thermometer verification passed (within 1.5%)

| Temperature Reading °F | | Absolute Temperature °R | | |
|---|---|---|---|---|
| | | °R = °F + 460 | | |
| Thermometer | Reference | Thermometer | Reference | % Difference |
| | | | | |

Comments:

Flow measurements were made in accordance with the latest revision of MAQ-127.
Measurements by:

| | | | |
|---|---|---|---|
| ____________________ | __________________________ | ________________ | _____/_____/_____ |
| Signature | Print name | Z-Number | Date |

| | |
|---|---|
| MAQ QA check by (initials): | MAQ review and approval by (initials): |

# Velocity Measurement Input Form (Form 5-R)

## (2 x 12 Round Stack or Duct)





TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

| Measurement Traverse A | | | | Measurement Traverse B | | | |
|---|---|---|---|---|---|---|---|
| Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) | Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) |
| A1 | | | | B1 | | | |
| A2 | | | | B2 | | | |
| A3 | | | | B3 | | | |
| A4 | | | | B4 | | | |
| A5 | | | | B5 | | | |
| A6 | | | | B6 | | | |
| A7 | | | | B7 | | | |
| A8 | | | | B8 | | | |
| A9 | | | | B9 | | | |
| A10 | | | | B10 | | | |
| A11 | | | | B11 | | | |
| A12 | | | | B12 | | | |

Measurements by:

____________________ ________________________ ______________ _____/_____/_____

Signature Print name Z-Number Date

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

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# Velocity Measurement Input Form (Form 5-S)

## (6 x 5 Rectangular Stack or Duct)



This form is from MAQ-127

TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

| Measurement Traverse A | | | | Measurement Traverse B | | | |
|---|---|---|---|---|---|---|---|
| Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) | Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) |
| A1 | | | | D1 | | | |
| A2 | | | | D2 | | | |
| A3 | | | | D3 | | | |
| A4 | | | | D4 | | | |
| A5 | | | | D5 | | | |
| | | | | | | | |
| B1 | | | | E1 | | | |
| B2 | | | | E2 | | | |
| B3 | | | | E3 | | | |
| B4 | | | | E4 | | | |
| B5 | | | | E5 | | | |
| | | | | | | | |
| C1 | | | | F1 | | | |
| C2 | | | | F2 | | | |
| C3 | | | | F3 | | | |
| C4 | | | | F4 | | | |
| C5 | | | | F5 | | | |

Measurements by:

| Signature | Print name | Z-Number | Date ______/______/______ |
|---|---|---|---|

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

# Velocity Measurement Input Continuation Form (Form 5-C)





TA/Building/ES ______-______-______ Measurement Date _____/_____/_____

| Measurement Traverse ____ | | | | Measurement Traverse ____ | | | |
|---|---|---|---|---|---|---|---|
| Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) | Point | Spacing (nearest 1/8 in) | Velocity Pressure (in $H_2O$) | Temperature (°F) |
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Measurements by:

____________________ ____________________ ____________________ _____/_____/_____
Signature Print name Z-Number Date

MAQ QA check by (initials):

MAQ review and approval by (initials):

Meteorology and Air Quality

# Stack Flow Data Transcription and Entry Verification Form

 This form is from MAQ-127

Place check in appropriate column:
**Column 1**: Data transcription verification **Column 2**: Data entry verification



| 1 | 2 | Stack ID | | 1 | 2 | Stack ID |
|---|---|---|---|---|---|---|
| | | TA-03, bldg-0029, ES-14, config. # 02 | | | | TA-41, bldg-0004, ES-17, config. #01 |
| | | TA-03, bldg-0029, ES-15, config. # 01 | | | | TA-48, bldg-0001, ES-07, config. # 01 |
| | | TA-03, bldg-0029, ES-19, config. # 01 | | | | TA-48, bldg-0001, ES-07, config. # 02 |
| | | TA-03, bldg-0029, ES-20, config. # 01 | | | | TA-48, bldg-0001, ES-54, config. # 01 |
| | | TA-03, bldg-0029, ES-23, config. # 01 | | | | TA-48, bldg-0001, ES-60, config. # 01 |
| | | TA-03, bldg-0029, ES-24, config. # 01 | | | | TA-50, bldg-0001, ES-02, config. # 01 |
| | | TA-03, bldg-0029, ES-28, config. # 01 | | | | TA-50, bldg-0037, ES-01, config. # 01 |
| | | TA-03, bldg-0029, ES-29, config. # 01 | | | | TA-50, bldg-0069, ES-03, config. # 01 |
| | | TA-03, bldg-0029, ES-32, config. # 01 | | | | TA-53, bldg-0003, ES-03, config. # |
| | | TA-03, bl[illegible]-0029, ES-33, [illegible]g. # 0[illegible] | | | | TA-[illegible] bl[illegible]-0003, ES[illegible]3, config. # |
| | | TA-03, bldg-0029, ES-37, con[illegible]g. # 0[illegible] | | | | TA-[illegible], b[illegible]g-0003, E[illegible], config. # |
| | | TA-03, bldg-002[illegible] ES-[illegible]. # [illegible] | | | | TA-53, b[illegible]g-0003, E[illegible]03, config. # |
| | | TA-03, b[illegible], ES[illegible]5, con[illegible] # [illegible] | | | | TA-53, [illegible]-0007, E[illegible], config. # |
| | | TA-03, bldg-0029, ES-46, config. # 02 | | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-03, bldg-0102, ES-22, config. # 01 | | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-03, bldg-0141, ES-01, config. # 01 | | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-03, bldg-0141, ES-01, config. # 02 | | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-16, bldg-0205, ES-04, config. # 02 | | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-21, bldg-0155, ES-05, config. # 01 | | | | TA-53, bldg-0007, ES-02, config. # |
| | | TA-21, bldg-0209, ES-01, config. # 01 | | | | TA-55, bldg-0004, ES-15, config. # 01 |
| | | TA-33, bldg-0086, ES-06, config. # 01 | | | | TA-55, bldg-0004, ES-16, config. # 01 |
| | | TA-33, bldg-0086, ES-06, config. # 02 | | | | |
| | | TA-33, bldg-0086, ES-06, config. # 03 | | | | |
| | | | | | | |

For the stacks checked above in **column 1**, I have performed a 100% verification to ensure the data have been **transcribed** correctly from the “raw” data forms to the “official” records form. The parameters verified are the duct static pressure, cross-sectional area of the duct/stack, atmospheric pressure, temperature of air in the stack, and the velocity pressure readings.

____________________ __________________________ ________________ _____/_____/_____

Signature Print name Z-Number Date

For the stacks checked above in **column 2**, I have performed a100% verification on all hand entered information to ensure the **data entered** into the “Stack” database corresponds to the data collected in the field. The parameters verified are the duct static pressure, cross-sectional area of the duct/stack, atmospheric pressure and temperature of air in the stack. Furthermore, I have performed a 10% verification on all electronically transferred information into the “Stacks” database to ensure the data corresponds with that collected in the field. The parameters verified are the velocity pressure readings.

____________________ __________________________ ________________ _____/_____/_____

Signature Print name Z-Number Date

# Flow Measurement Calculation Form (Form 6)



This form is from MAQ-127

TA/Building/ES ______-______-______ FE(s) ________________________

Measurement Date _____/_____/_____ Fan Exhaust Configuration _________

Profile Measurement Number _________

**Step 1: Calculate the stack gas average absolute temperature, $T_{s(avg)}$**

a) From field input form, determine $t_{s(avg)}$ = _________ °F

b) Calculate the absolute temperature, $T_{s(avg)} = t_{s(avg)} + 460$ = ________ °R

**Step 2: Calculate the exhaust stack absolute pressure, $P_s$**

b) From the field input form, record the barometric reference pressure, $P_{ref}$ = _________ " Hg

b) Adjust for elevation

= $P_{ref}$ + [Elevation $_{prof}$ - Elevation $_{ref}$] (-0.1 "Hg / 100 ft)

= ______ "Hg + [__________ ft - ________ ft] (-0.1/100)

= _____________ "Hg

d) From the field input form, record the stack static pressure, $P_g$ = __________ " wg

e) Convert the static pressure from inches w.g. to inches Hg

$P_g$ = [$P_g$ "wg] (62.4 / 846.9) "Hg

= __________ (62.4 / 846.9) "Hg

= __________ "Hg

f) Calculate the exhaust stack absolute pressure

$P_s = P_{bar} + P_g$

= ________ + ________ = ________ "Hg

**Step 3: Calculate the molecular weight of the stack gas, $M_s$**

a) From Method 4 or 5 $B_{ws}$ = __________ (**Always** use 0 humidity for conservatism)

b) From Method 3 $M_d$ = __________ (Use 29 for air)

c) Calculate $M_s$ $M_s = M_d (1 - B_{ws}) + 18.0\ B_{ws}$

= ________ ( 1 - ________ ) + 18.0 ( ________ )

= ________ lb / lb mole

# Flow Measurement Calculation Form (Form 6), continued





**Step 4: Calculate K**

a) K = (85.49) (60) SQRT[ $T_{s(avg)}$ / $P_sM_s$ ]

= (85.49)(60) SQRT [ ________ / (________)(________)] = ____________

**Step 5: From the field input form, calculate the average velocity head of the stack gas**

a) $$(\sqrt{\Delta p})_{(avg)} = \frac{\sum_{i=1}^{n} \sqrt{\Delta p}}{n}$$ = __________ inches water

**Step 6: Calculate the average stack gas velocity (actual), $v_s$**

a) $$v_s = C_p K (\sqrt{\Delta p})_{avg}$$ ft/min

= ________ * ________ * ________

= ________ ft/min

**Step 7: Calculate the exhaust stack flow rate (actual), Q**

a) Record the stack/duct cross-sectional area from profile measurements

A = __________ $ft^2$

b) Q = $v_s$ * A

= ________ * ________

= ________ acfm

**Step 8: Calculate the exhaust stack gas dry volumetric flow rate (standard), Qsd**

a) $$Q_{sd} = (1 - B_{ws}) v_s A \frac{T_{std}}{T_{s(avg)}} \frac{P_s}{P_{std}}$$

$Q_{sd}$ = [ 1 - ________ ] * ________ * ________ [ ________ / ________ ] [ ________ / ________ ]

$Q_{sd}$ = ____________ scfm

Calculations by:

| ____________________ | __________________________ | ________________ | ______/______/______ |
|---|---|---|---|
| Signature | Print name | Z-Number | Date |

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

# Cross-Sectional Area Worksheet (Round Exhaust Stack or Duct) (Form 7-R)

 This form is from MAQ-127

TA/Building/ES ______-______-______ FE(s) ________________________

Profile Measurement Number __________

**1. Sketch the exhaust stack or duct cross- section and label the traverses. Include any references in the sketch.**

**2. Measure the diameters to the nearest 1/8 inch**

| Traverse Number | Measured Diameter (nearest 1/8") | Diameter (decimal format in inches) |
|---|---|---|
| $d_1$ | | |
| $d_2$ | | |
| $d_3$ | | |
| $d_4$ | | |

Measurements by:

______________________ ____________________________ _________________ _____/_____/_____
Signature Print name Z-Number Date

**3. Calculate the cross- sectional area. Do not round d or $\pi$. Round final number to three decimal places.**

Round: $Area = \pi \left[ \frac{d}{2} \right]^2 \left[ \frac{1}{144} \right]$ **OR** Oval: $Area = \frac{\pi * d_1 * d_2}{576}$ Area = ________________ sq feet

Calculations by:

______________________ ____________________________ _________________ _____/_____/_____
Signature Print name Z-Number Date

| MAQ QA check by (initials): | MAQ review and approval by (initials): |
|---|---|

Meteorology and Air Quality

# Cross-Sectional Area Worksheet (Rectangular Exhaust Stack or Duct) (Form 7-S)



This form is from MAQ-127

TA/Building/ES ______-______-______ FE(s) ________________________

Profile Measurement Number __________

**1. Sketch the exhaust stack or duct cross- section and label the traverses. Include any references in the sketch.**

**2. Measure the widths and depths to the nearest 1/8 inch**

| Traverse Number | Measured Diameter (nearest 1/8") | Diameter (decimal format in inches) |
|---|---|---|
| Width 1 (W1) | | |
| Width 2 (W2) | | |
| Depth 1 (D1) | | |
| Depth 2 (D2) | | |

Measurements by:

____________________ ____________________________ _________________ _____/_____/_____

Signature Print name Z-Number Date

**3. Calculate the cross- sectional area. Round final number to three decimal places.**

$$Area = \left[\frac{W1 + W2}{2}\right]\left[\frac{D1 + D2}{2}\right]\left[\frac{1}{144}\right]$$ sq feet

Area = __________________ sq feet

Calculations Performed by:

____________________ ____________________________ _________________ _____/_____/_____

Signature Print name Z-Number Date

MAQ QA check by (initials):

MAQ review and approval by (initials):